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Using GAMS for River Basin Management 1

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YOU WILL LEARN

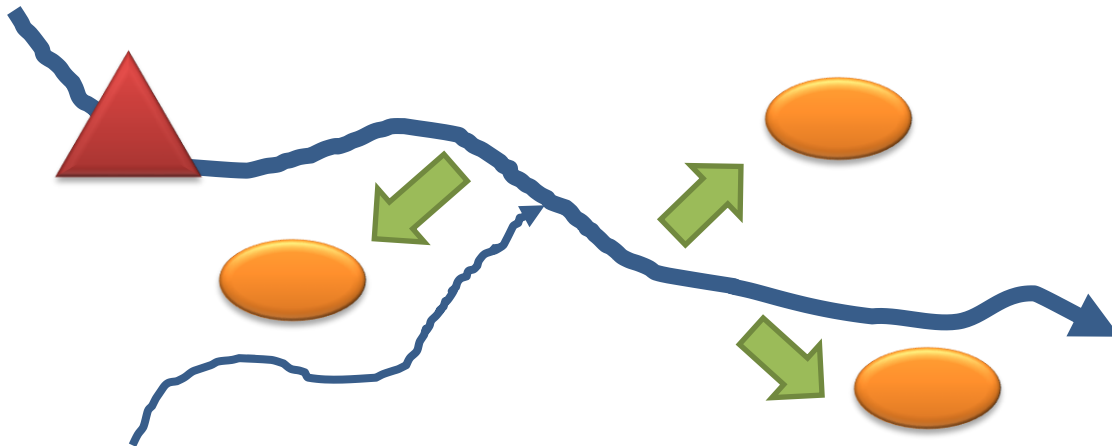
- Quick review of single reservoir operation
- The node-link structure of a river basin (routing)
- Node-link structure in GAMS
- River basin management – GAMS exercise

QUICK REVIEW OF SINGLE RESERVOIR OPERATION

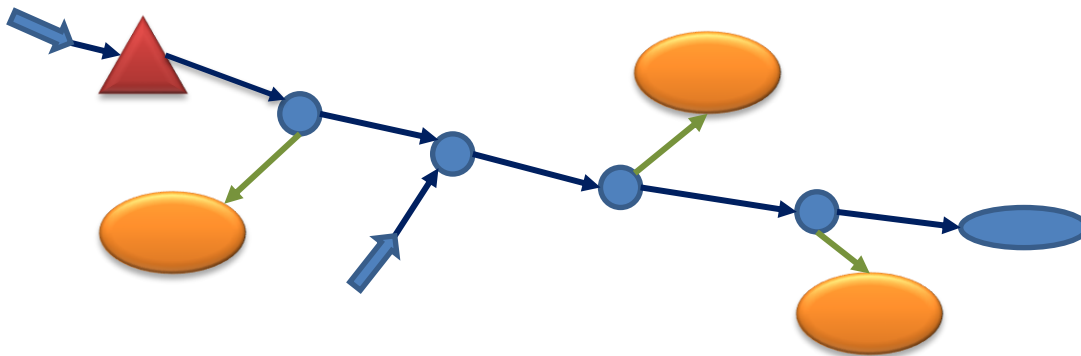
- In the single reservoir example from last class, the upstream-downstream relationship between the three demand sites was ignored. In most real world cases, the location of users should not be ignored.
- Also, the single reservoir model consisted of only a single year. The ability to create multi-year runs is needed. The loop function in GAMS will be introduced in the next handout.

THE NODE-LINK STRUCTURE OF A RIVER BASIN (ROUTING)

- To make the single reservoir example more realistic, we have to consider the **upstream-downstream relationship** between **every component** of the system.
- For a system model (not only GAMS, but any other computer language you might use), identifying the **node-link structure of the river basin system** is an important step.
- Coding the river basin system in a node-link structure is based on **graphic theory**, whereby the **conservative transport of water** is carried out through a directed graph. At the nodes of the graph, the volume of water resources may change according to certain rules.
- Consider the following river system schematic:



- Types of nodes
 - Inflow node
 - Reservoir node
 - Demand node
 - River flow node
 - Sink node
- For each type of node, the **inflow** and **outflow** are calculated. Inflow is calculated as the sum of all releases or inflows from all related upstream nodes. Outflow is the sum of all flow to downstream and also any withdrawals to demand nodes. In this way a mass balance is maintained at each node in the system.
- We can translate the above schematic into the following **system map**



- This system has 2 inflow nodes, 1 reservoir node, 3 demand nodes, 4 river flow nodes and 1 sink node
- The arc that connects pair of nodes is defined as a link

NODE-LINK STRUCTURE IN GAMS

- Some additional terms are needed to describe the node-link structure in GAMS coding.
 - *SET and subset*
Subsets of sets are used to partition the set of nodes into different types: river flow nodes, supply nodes, water user nodes, and reservoir nodes.

This facilitates the construction of a general model where different nodes serve different functions in the network and transform water flows or other properties in different ways.

- *ALIAS and two-dimensional set*
Alias is used to define another set of nodes exactly the same as the first set (e.g. Set N and Set N1). That way the two sets can be used to refer to two different nodes simultaneously in a **two-dimensional set**.

Two-dimensional sets are used **to establish the topology of the network**, in other words, the node-link structure (e.g. define “N1_from_N (N, N1)” in GAMS).

These connections are indicated by using the ‘**dot**’ operator between two members of the two sets, e.g. “**Inflow_1.Res_1**” where **Inflow_1** is from **Set N** and represents the node for Inflow 1 and **Res_1** is from **Set N1** and represents the node for reservoir 1.

- *The use of dollar sign operator “\$” and “ORD” operator*
 The ‘**\$**’ or ‘conditional’ operator is used in the water balance equation in conjunction with the ‘**ORD**’ operator to pick out the initial time period and make sure that the initial storage volume ‘beg_s’ is used as the previous month’s storage.

The effect of this is that when the condition after the ‘\$’ is true then the value before the ‘\$’ sign is used, otherwise it is omitted. The **ORD (Set)** represents the ordinal value of the index of the set.

An example for the use of these two terms: **Beg_S\$(ord(t) eq 1) + S(i,t-1)\$ (ord(t) gt 1)** means when the **index of Set t equals 1**, the model will use Beg_S (initial value of S) and when **index of Set t greater than 1** model will use S(i,t-1).

- Example code of water balance equation

$$S(i,t) = \text{Beg_S} \$ (\text{ord}(t) \text{ eq } 1) + S(i,t-1) \$ (\text{ord}(t) \text{ gt } 1) + \text{SUM}(\text{source inflow}) + \text{SUM}(\text{Upstream inflow}) - \text{SUM}(\text{Downstream outflow}) - \text{SUM}(\text{Withdrawal});$$

This means **Storage at time t = Storage at time t-1 + source inflow at time t + upstream inflow at time t - downstream outflow at time t - withdrawal outflow at time t**

RIVER BASIN MANAGEMENT – GAMS EXERCISE

- Using the schematic as an exercise

- All necessary data are given below. The objective is to **minimize the difference between water demand and supply**

Monthly water demand for three demand sites (unit: million cubic meter, MCM)

	F1	F2	F3
t1	239.6	432.3	708.9
t2	239.6	432.3	708.9
t3	239.6	432.3	708.9
t4	239.6	432.3	708.9
t5	299.7	528.6	869.3
t6	299.7	528.6	869.3
t7	299.7	528.6	869.3
t8	294.3	519.9	854.8
t9	275	489	803.3
t10	275	489	803.3
t11	275	489	803.3
t12	275	489	803.3

Inflow from two tributaries (MCM)

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12
If1	426	399	523	875	2026	3626	2841	1469	821	600	458	413
If2	211	199	303	555	634	1088	1151	1337	798	498	258	203

Reservoir information

Capacity: 9,500 MCM; dead storage: 5,500 MCM; initial storage: 8,000 MCM

Environmental requirement

Minimum flow requirement to flow into the downstream lake: 150 MCM per month.

It is an exercise, so you have to code it by yourself. But let me give you the [Sets](#) that are necessary for the coding.

SETS

I inflow nodes /If1, If2/
 N river or reservoir nodes /Res, Rv1, Rv2, Rv3, Rv4, Rvend/
 D demand nodes /F1, F2, F3/
 t month /t1*t12/
 Lak(N) reservoir or lake or sea /Res, Rvend/
 ;

Hint1: use alias to “copy” Set N as N1

Hint2: Define two- dimensional sets between “I and N”, “N and D”, and “N and N1”

Hint3: Define a positive variable $F(t, N, N1)$ to represent flow from N to N1 at time t.

Hint4: The water balance equation will be something like

Balance(t,N)..

S(t,N) =E=
**river inflow*
+ SUM(I\$IN(I,N),Q(t,I))
**all upstream inflow from river or reservoir*
+ SUM(N1\$NN(N1,N), F(t,N1,N))
**all downstream outflow to river*
- SUM(N1\$NN(N,N1), F(t,N,N1))
**water withdrawal*
- SUM(D\$ND(N,D), W(t,N,D))
**previous storage*
+ beg_S(N)\$(ORD(t) EQ 1) + S(t-1,N)\$(ORD(t) GT 1);